RESEARCH
PUBLICATION
NO. 20

AN EVALUATION OF EFFLUENT POLISHING PROCESS INSTALLATIONS

THE ONTARIO WATER RESOURCES COMMISSION

AN EVALUATION

OF

EFFLUENT POLISHING PROCESS INSTALLATIONS

S. A. Black
Division of Research

January 1967

AN EVALUATION OF EFFLUENT POLISHING PROCESS INSTALLATIONS

SUMMARY

Process evaluation studies were carried out on the Don West, Dixie and Erindale Water Pollution Control Plant effluent polishing installations. The Don West installation consists of a detention pond while those of the Dixie and Erindale plants consist of sand filter bed systems.

The detention pond acting as an effluent polishing facility is capable of substantial removal of Biochemical Oxygen Demand (35%) and Suspended Solids (75%). Little nutrient removal is effected without the complete removal of algal cells from the effluent. The outstanding feature of the detention pond is the production of a highly oxygenated effluent for discharge to the receiving stream.

The open sand filter beds were quite ineffective in additional removal of Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) at the Dixie Plant but, while operating, removed substantial amounts of both BOD and SS from the Erindale WPCP effluent. This is as would be expected since the BOD and SS of the Dixie WPCP effluent averaged only 4.7 and 9.4 ppm, respectively, while that of Erindale averaged 57 and 78 ppm, respectively. Under the high SS content of the Erindale WPCP effluent, the filter beds tended to clog up after only four to five days operation. The sand then had to be raked and tilled.

This study indicated that sand filters are of use only where WPCP effluent BOD and SS are in the range of 10 to 30 ppm. At values above these, clogging occurs, while at values below these, the additional treatment is almost negligible and should be considered only where very little or no dilution water is available.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This study was undertaken by the Field Projects Branch, Division of Research, to evaluate various existing secondary treatment plant effluent polishing installations within Metro Toronto.

The study consists of two related phases:

(a) The evaluation and comparison of effluent polishing process installations, and

(b) relating the performance of these installations to the receiving water quality wherever this was possible.

An investigation into currently used effluent facilities revealed the use of the following process installations in Ontario:

(1) Slow sand filters-these are of similar construction to slow sand filters at waterworks with no back-washing or aeration facilities provided. Although used extensively in Ontario they can only be used in the summer season because of freezing problems. Large areas are required (1 - 3 MGD/acre) and clogging problems occur when a poor secondary effluent is fed. Efficiencies are reported to be between 60 to 80% for SS removal and 40 to 65% for BOD.

(2) Underdrain Tile Field-this method has limited use in Ontario on a municipal basis. It consists of an underground gravel bed with a distribution and collection system similar to that of the tile bed used for septic tank drainage. This method may be used for year round operation but a large land area is required and clogging of the bed requires extensive rebuilding. Efficiencies are reported to be similar to those of the slow sand filters.

(3) Lagooning-several installations are in use in Ontario but very few operational results are available. A recent pilot study at Brampton indicated high fluctuations in BOD and SS removal efficiencies.

(4) Aerated Pond-no full scale installations are reported as yet in operation in Ontario. A pilot study at Brampton revealed that under specified loading and operation limits BOD and SS reductions of the order of 50% may be achieved.

(5) Microstrainers-this apparatus was used in 1960 for tests at Brampton. This apparatus may be used for year round operation but requires high initial and operating costs with continuous attention. Up to 50 to 60% of the

suspended matter and BOD was removed by the process but there was little to no improvement in bacteriological quality.

(6) Rapid Gravity Sand Filter-these are similar in construction and operation to the conventional rapid sand filters used in water treatment. These filters require skilled maintenance and operation and because of the greater load of organic matter and ammonia in sewage then in water, a higher proportion of wash water is required for their cleaning. Greater facilities for aeration are also required because of the higher demand for oxygen for nitrification and other biochemical processes taking place during the passage of effluent through the sand. Removals in the order of 50% BOD and 70% SS are achieved.

This study presents an evaluation of a lagoon or detention pond and two slow sand filter beds as effluent polishing facilities. The performance of each polishing installation has been assessed by recording the relevant quality aspects of the influent and effluent. Of particular importance in effluent polishing installations are the suspended solids, Biochemical Oxygen Demand and dissolved oxygen contents.

2.0 DON WEST WPCP

2.1 Treatment Facility

The effluent polishing facility at the Don West WPCP consists of a one acre detention pond providing a detention period of 3.75 days at the design flow of 0.33 Imp. mgd. Figure 1 gives a plan view of the polishing facility.

2.2 Plan of Study

In view of the variable secondary effluent quality and of the detention period involved, a study period of three weeks was chosen on which to base the evaluation of the process. A 24 hour composite sample of WPCP effluent and a grab sample of pond effluent were collected daily. Daily determinations of pH, DO and temperature were made at the plant site and samples were returned to the OWRC laboratories for daily determinations of BOD, COD and SS. Several samples were submitted at regular intervals for extensive chemical analyses and also samples of pond effluent for algae determinations.

2.3 Detention Pond Data

The average data for the three week study period is presented in Table 1. As can be seen, the average flow through the plant was much below the design flow, averaging only 172,000 Imp. gpd, giving an actual retention period in the pond to 5.52 days.

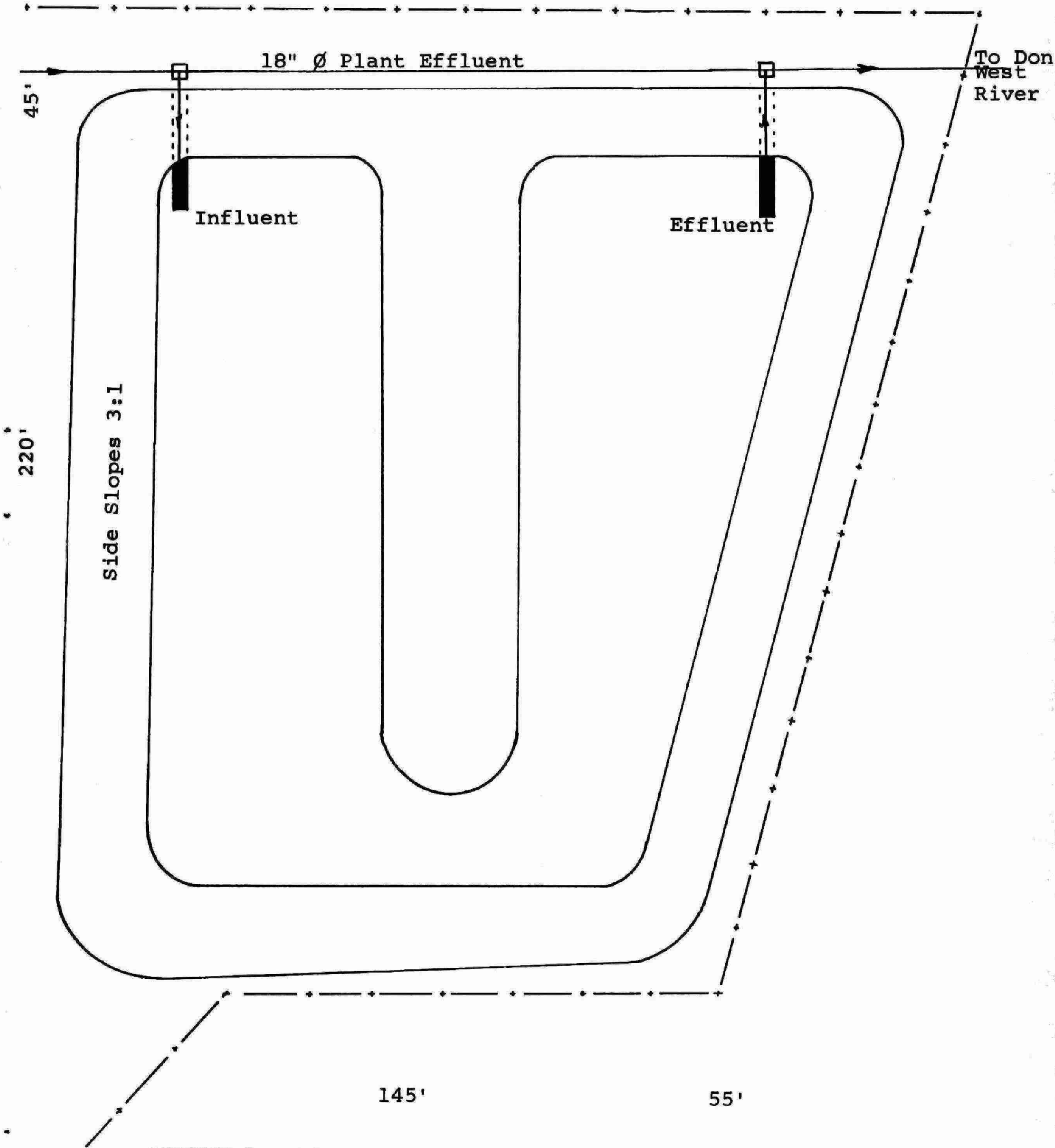

FIGURE 1 - Plan view of the Don West WPCP effluent polishing facility

Table 1

Detention Pond Data *

	Influent	Effluent
Flow IGPD	172,000	
Temperature ^{o}C	10.1	9.6
BOD - 5 day mg/l	14.6	9.2
Suspended solids mg/l	45.0	11.0
pH	7.5	8.0
COD mg/l	151.0	115.0
Organic Nitrogen mg/l	10.4	11.3
Free Ammonia mg/l	9.4	11.4
Nitrate plus Nitrite	1.12	1.21
Soluble Phosphorus mg/l	4.2	4.7
Dissolved Oxygen mg/l	3.2	12.9
ABS mg/l	0.3	0.2
Chloride mg/l	509.0	619.0

* Average of 3 weeks Data (April 14 - May 6, 1966)

Derived Computations

Detention time - days	5.52
BOD Loading	
lbs applied BOD per M. Cu. Ft.	0.164
lbs applied BOD per Acre Water Surface per day	25.0
Removal of BOD	
lbs BOD removed per Acre of Water Surface per day	8.6

2.4 Discussion of Data

(a) BOD and Suspended Solids Removal

Table 2 indicates the percent removal of BOD and suspended solids during the test period. Column 1 expresses the removal by the activated sludge process, column 2 expresses activated sludge plus pond removal with reference to the raw sewage and column 3 expresses pond removal with reference to the activated sludge effluent.

Table 2

Detention Pond Per Cent Removal (Don West)

	1	2	3
BOD	85	91	34
Suspended Solids	68	92	76

As can be seen, the detention pond was quite effective in providing additional BOD and SS reductions, increasing overall reduction to 91 and 92% respectively.

(b) Nutrient Removal

As can be seen from Table 1, virtually no removal of nitrogen was accomplished in the detention pond. Filtration of the pond effluent to remove algae populations, however, produced an almost 50% reduction in organic nitrogen from the effluent.

No reduction occurred in soluble phosphorus. Total phosphorus was reduced by approximately 2 ppm, probably due to the precipitation of algae and of calcium phosphate at high pH values, to the bottom of the pond. During the winter season dissolution of the previously precipitated phosphates occurs.

(c) Oxygen Relationships

Perhaps the most outstanding feature of the detention pond treatment was the production of a nearly fully oxygenated effluent for discharge to the river and so avoiding harmful effects on stream biota and fisheries.

As seen in Table 1, the dissolved oxygen in the activated sludge effluent averaged only 3.2 ppm, ranging to as low as 0.5 ppm. The detention pond dissolved oxygen, on the other hand, averaged 12.9 ppm and reached a minimum of 7.2 ppm during the study.

2.5 Effect of Waste Discharge on Receiving Stream

An attempt was made to determine the effect of the detention pond effluent upon the quality of the receiving stream. The dilution ratio of the stream during times of observations varied between approximately 100 times and 10 times the waste effluent. Dissolved oxygen deter-

minations of the stream above and below the outfall site indicated no detrimental effects at flows over approximately 40 times the waste effluent. At flows below this a slight dissolved oxygen sag curve developed, but at no time was the dissolved oxygen observed to be below 65% saturation.

Observations of stream biota indicated no detrimental effects of waste at distances greater than 5-600 yards from the outfall.

2.6 Summary and Conclusions

The detention pond, acting as an effluent polishing facility is capable of substantial removal of BOD and suspended solids. Little nutrient removal is effected without the filtration of algae from the effluent.

The detention pond acts as a buffer between the treatment plant and the river (see Table 3) in that any excess of suspended sludge or humus is held back and diluted in the pond. Any sudden shock load of toxic or undesirable substance in the plant effluent is diluted by the larger volume of the receiving waters in the pond. This affords a protection to fish life in the river from any harmful matter in the effluent.

The nature of the detention pond effluent should

eliminate the build up of sludge in the stream at the outfall location.

The outstanding feature of the detention pond is the production of a highly oxygenated effluent for discharge to the receiving stream.

Table 3

WPCP and Detention Pond Effluent Qualities

	WPCP Effluent			Pond Effluent		
	BOD	SS	DO	BOD	SS	DO
Max.	23.0	83	6.6	13.0	20	16.8
Min.	4.4	24	0.5	5.2	3	7.2
Avg.	14.6	45	3.2	9.2	11	12.9

3.0 DIXIE WPCP

3.1 Treatment Facility

Effluent polishing at the Dixie WPCP is provided by a slow sand filter bed. The filter media is composed of 6" of 3/4" to 1" stone, 3" of 3/8" to 1/2" gravel, 3" of 1/8" to 1/4" gravel and 18" of sand. The filter bed is made up of three separate units with a total of 8,125 sq ft of area. The effluent is fed consecutively into the three beds at a rate of 1.34 MG/acre/day providing an organic loading of 56 lb BOD/acre-ft/day. Figures 2 and 3 present views of the installation.

3.2 Plans of Study

A study period of three weeks was chosen as the period for data collection on which to base the evaluation of the sand filter as an effluent polishing process. Twenty-four hour composite samples of WPCP and filter effluents were collected daily for the three week period. Daily determination of pH, DO and temperature were made at the plant site and the samples were then returned to the laboratories for determination of BOD, COD and SS. Several samples were submitted at regular intervals for extensive chemical analyses.

FIGURE 2 Dixie Sand Filter Beds

FIGURE 3 Distribution of Effluent over Dixie Filter Bed

3.3 Sand Filter Operation

The mechanism of BOD removal in the sand filter is similar to that of the activated sludge process. A large portion of the liquid applied to the surface of a filter passes rapidly through the filter and the remainder slowly trickles over the surface of the slime growth layer which establishes itself within the filter media. Removal occurs by biosorption and coagulation from that portion of the flow which passes rapidly through the filter and by the progressive removal of soluble constituents from that portion of the flow with increased residence time.

3.4 Filter Bed Data

The average data for the three week study period are presented in Table 4. The average flow through the plant is somewhat below the design flow, averaging 250,000 I.G.D.

Table 4

Filter Bed Data *

	Influent		Effluent
Flow I.G.D.		250,000	
BOD - 5 day mg/l	4.7		4.6
Suspended Solids mg/l	9.4		7.8
pH	7.3		7.4
COD mg/l	51		47
Organic Nitrogen mg/l	4.2		2.1
Free Ammonia mg/l	2.0		2.0
Nitrite plus nitrate mg/l	13.5		8.4
Soluble Phosphorus mg/l	19.2		18.2
Dissolved Oxygen mg/l	3.0		9.1
ABS mg/l	2.5		2.3

* Average of 3 Weeks Data (May 10 - June 10, 1966)

Derived Computations

Loading - hydraulic	1.34 MG/acre/day
- organic	5.6 lb BOD/acre-ft/day
Removal of BOD	0.43 lb BOD/acre-ft/day

3.5 Discussion of Data

(a) BOD and Suspended Solids Removal

Table 5 indicates the percent removal of BOD and SS during the test period. Column 1 expresses the removal by the activated sludge process, column 2 expresses activated sludge plus filter removal with reference to the raw sewage and column 3 expresses filter removal with respect to the activated sludge effluent.

Table 5

Filter Bed Per Cent Removal (Dixie)

	1	2	3
BOD	96.1	96.2	1.6
Suspended Solids	92.6	93.5	17.3

The reduction in BOD achieved by the filter beds was almost negligible, increasing the reduction achieved by the activated sludge process by only 0.1%. The reduction in suspended solids was somewhat higher increasing the total reduction from 92.6% to 93.5%.

The small increase in BOD removal may perhaps be attributed to the high quality of the activated sludge effluent. From the low suspended solids level, it would appear that the BOD present was mostly in the dissolved

state and thus difficult to remove be filtration unless there is a well developed slime layer in the filter. The high fluctuation which occurred in the BOD of the filter bed effluent indicated a build-up of slime followed by a sloughing-off period. Perhaps this was due to the low organic loading in relation to the hydraulic loading.

(b) Nutrient Removal

Table 1 indicates that the organic nitrogen was decreased by 50% in the sand filter, while there was virtually no removal of free ammonia. There was a 38% reduction in nitrites and nitrates, the high concentration of these in the WPCP effluent indicating that the plant treatment was well within the nitrification stage and almost all free ammonia had been converted to nitrite and nitrate.

Very little reduction in soluble phosphorus was noticed.

(c) Oxygen Relationship

Perhaps the only significant improvement of the waste effluent due to the action of the sand filter was the oxygenation of the effluent. Dissolved oxygen concentrations were increased from an average of 3.0 ppm to 9.1 ppm. The high dissolved oxygen level of the effluent as it enters the receiving stream is important in avoiding harmful effects on the stream biota and fisheries.

3.6 Summary and Conclusions

The results of this study indicate very little reduction of either BOD or suspended solids by the sand filter beds. This fact, however, may be attributed to the high quality of the secondary effluent; the BOD and suspended solids of which averaged 4.7 and 9.4 ppm, respectively. Thus, it would appear that with such a high quality waste little improvement may be achieved through the use of a sand filter bed for effluent polishing, except perhaps for the high oxygenation effect of the beds on the waste.

Reduction of the organic nitrogen in the order of 50% was achieved, while very little reduction in soluble phosphorus was noted.

It must be noted that under Ontario's climatic conditions the open sand filter beds may only be used during the warmer season from April to October.

4.0 ERINDALE WPCP

4.1 Treatment Facility

The effluent polishing facility at the Erindale WPCP consists of two 70' x 100' slow sand filter beds. The filter media is composed of 3' of clean gravel, 3" of 3/8" to 1/2' pea gravel and 24" of 40 mesh clean sand. An undetermined percentage of the plant effluent was fed simultaneously to the two filter beds by an automatically controlled level device.

4.2 Plan of Study

This study was to be carried out in much the same manner as the Dixie study. However, because of the clogging problems the study could only be carried out over a period of four to five days at a time. Also since flows to the filter were not known the loadings to the filter beds were not determined.

4.3 Filter Bed Data

The average data for the period of study are presented in Table 6. As can be seen, the secondary treatment plant effluent was very poor with respect to BOD and SS.

Table 6

Filter Bed Data *

	Influent	Effluent
BOD - 5 day mg/l	57	26
Suspended Solids mg/l	78	20
Organic Nitrogen mg/l	47	35
Free Ammonia mg/l	21	20
Nitrite plus Nitrate mg/l	.10	.10
Soluble Phosphorus mg/l	34	21
Dissolved Oxygen mg/l	2.4	8.6

* Average of 3 weeks Data (August 24 - September 14, 1966)

4.4 Discussion of Data

(a) BOD and SS removal

Table 7 gives the percent removal of BOD and SS during the test period. Column 1 expresses the removal by the activated sludge process, column 2 expresses activated sludge plus filter removal with respect to the raw sêwage and column 3 expresses filter removal with respect to the activated sludge effluent.

Table 7

Filter Bed Per Cent Removal (Erindale)

	1	2	3
BOD	71.9	87.2	54
Suspended Solids	77.7	94.3	74

The filter beds were quite effective in reducing the effluent BOD and SS solids. BOD reduction was increased from 71.9% to 87.2% while suspended solids reduction was increased from 77.7% to 94.3%. As has been stated however, clogging problems did occur at the high influent suspended solids concentrations experienced.

(b) Nutrient Removal

Table 6 shows an organic nitrogen reduction of 26%, and a soluble phosphorus reduction of 38% by the filter bed. The low concentration of nitrite and nitrate indicate very little nitrification taking place in the treatment process. There was virtually no reduction in free ammonia.

(c) Oxygen Relationships

Here again the sand filter was very effective in raising the dissolved oxygen content of the waste to an acceptable level for introduction to the receiving stream. However, because of the higher BOD level of the final effluent, the effect of this waste on its receiving stream would be greater than that from the Dixie plant.

4.5 Summary and Conclusions

The results of this study indicate a high reduction of BOD and suspended solids by the sand filter while it was operative. Clogging of the filters occurred after four to five days and the beds had to be bypassed.

A slow sand filter then, cannot be used as a substitute to reliable secondary treatment and the suspended solids concentration to such a filter must be maintained at no greater than 25 to 30 ppm or filter clogging will occur.

The sand filter, in this case removed fairly large concentrations of organic nitrogen and of soluble phosphorus.

A highly oxygenated effluent was produced for discharge to the receiving stream.